Differential Diffusion In Ocean Mixing

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LONG-TERM GOAL

My long term goal is to understand the processes which mix heat (temperature T) and salt (S) in the stratified interior of the ocean well enough that they can be accurately parameterized in ocean models. Of particular interest to me at the present time is the possibility that turbulence in parameter ranges typical of the stratified interior of the ocean acts to transport T and S differentially, even in situations where double diffusion is not possible.

OBJECTIVES

The goal of this project is to determine the range of external conditions (ie Reynolds number, Froude number etc) under which differential diffusion occurs, and to quantify the magnitude of the associated differential transports.

APPROACH

I am employing a three-pronged approach which makes coordinated use of laboratory, computational, and observational techniques. First, I am working with colleagues B. Ruddick (Dalhousie) and D. Hebert (URI) to make laboratory determinations of differential diffusion associated with sporadic internal wave breaking, using two conservative fluorescent dyes (with difference in molecular diffusivities similar to that between T and S) to eliminate problems with sidewall heat losses experienced in previous experiments at IOS. Secondly, I am carrying out three-dimensional computer simulations of differential diffusion, to check the reliability of previous two-dimensional results (Merryfield et al., 1998: see Figure 1). Finally, I am analyzing field observations of evolution of T/S structure (see Figure 2) which may be the result of differential diffusion.

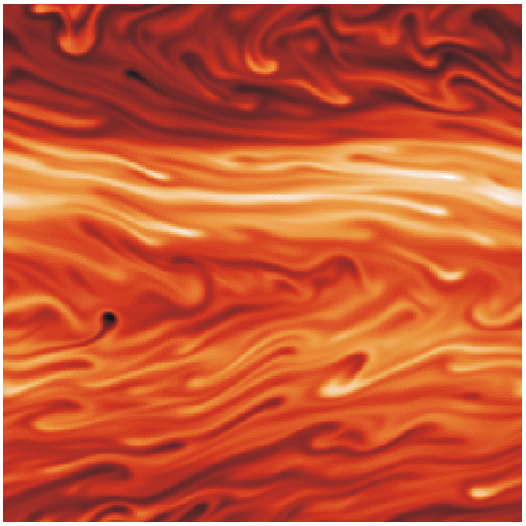

Figure 1: Salinity field from a two-dimensional computer simulation of decaying turbulence (Merryfield et al. 1998). A new 3D code will explore potential effects on differential diffusion of three-dimensionality of the underlying flow field.

WORK COMPLETED

The laboratory set-up has been completed (wave generation unit, illumination system and CCD camera system for dye measurement) and analysis methods are being developed. A complete set of two-dye experiments will be available by spring 2000.

The three-dimensional computer simulation code has been written and is presently undergoing testing.

Basic processing of the CTD data and the associated velocity field data has been completed.

RESULTS

All three approaches to the problem of differential diffusion are now operational. The numerical experiments should be able to achieve the parameter ranges of the laboratory runs, and preliminary estimates suggest that the field observations will also converge.

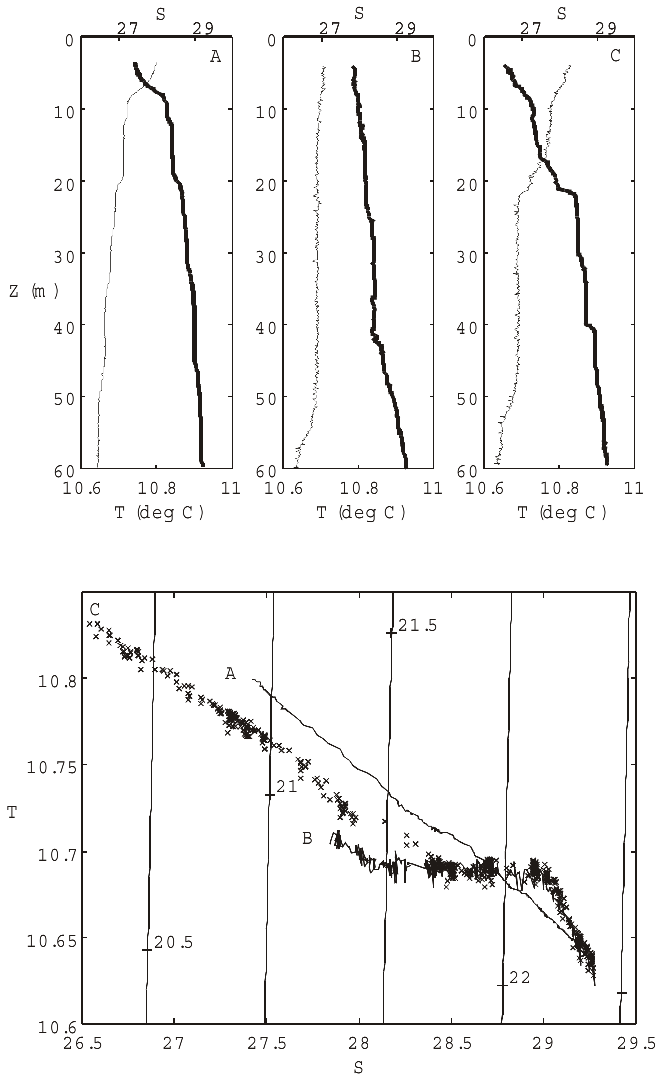

Figure 2: The upper panels show free-fall CTD profiles of T (light lines) and S (heavy lines) taken from an anchored ship at (A) high water slack tide, and (B,C) as an ebb tidal flow increased over the subsequent 3 hours. "Ordinary" mixing of the water column in (A) would retain the linear relation shown in the T/S plot below. Instead, the turbulence (revealed variously by large overturning scales (B) and, in other parts of the data set, by critical mean shears and large vertical velocities) results in a strongly nonlinear deformation of the T/S relation, in the direction expected from differential diffusion with $K_T > K_S$, despite the fact that the mean gradients of both components are stabilizing. If this interpretation can be confirmed, these will be the first oceanic observations of an effect which has been observed in both laboratory experiments (Altman and Gargett 1987; Saylor 1993) and direct numerical simulations (Merryfield et al. 1998).

IMPACT/APPLICATIONS

The possible presence of differential diffusion in the ocean has enormous implications for (1) correct interpretation of standard microscale mixing estimates, (2) estimation of mixing from conservative tracer release experiments, and consequently for (3) parameterization of vertical mixing in all numerical models of the ocean. Because ocean models are extremely sensitive to these parameterizations, and because turbulence in much of the stratified interior of the ocean occurs in the low Reynolds number, O(1) Froude number range within which existing numerical simulations suggest differential diffusion is significant, the results of this research are of major importance to the field of predictive ocean modeling.

TRANSITIONS

Not yet

RELATED PROJECTS

B. Ruddick and D. Hebert hold an NSF grant for the laboratory part of this research, which is being carried out in Ruddick's lab at Dalhousie University: ONR support enables my participation in the experiments and analysis.

REFERENCES

Altman, D.B. and A.E. Gargett. 1987: Differential property transport due to incomplete mixing in a stratified fluid, Proc. Third Int. Symp. on Stratified Flows, Pasadena, California Institute of Technology.

Merryfield, W.J., G. Holloway and A. E. Gargett. 1998a. Differential vertical transport of heat and salt by weak stratified turbulence. Geophys. Res. Letters, 25, 2773-2776.

Saylor, J.R. 1993: Differential diffusion in turbulent and oscillatory, non-turbulent, water flows, Ph.D. Thesis, Yale University.

PUBLICATIONS

Gargett, A. E. 1999: Velcro measurements of turbulence kinetic energy dissipation rate ε. J. Atmosph.Oceanic Tech., 16(12), 1973-1993. (Note: final results of the previous phase of this grant.)